Changes in the distributions of larval, juvenile, and adult witch flounder in the Northeast U.S. Shelf Ecosystem: updates through 2015

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Introduction

The intent of this working document was to update analyses examining the distribution shifts of witch flounder (*Glyptocephalus cynoglossus*) in the Northeast U.S. Shelf Ecosystem from Walsh et al. (2015). Methods were described in Walsh et al. (2015), and results presented here were updated with data through 2015, and also include new analysis of juvenile (< 30 cm) witch flounder.

Methods

Changes in distribution

Briefly, the relative proportion (percent of annual sum) of estimated absolute number of larvae, juveniles, and adults within each of 47 Ecosystem Monitoring (EcoMon) strata were used to examine changes in distribution. The EcoMon strata, which combine some bottom trawl survey strata, were used to allow comparisons to be made among the life stages, and the larval strata were originally developed using the stratum design of the bottom trawl survey. Significant differences of stratum proportions between time periods were calculated using a Kruskal-Wallis chi-square. The stratum-specific Kruskal-Wallis H values were considered a measure of the magnitude of change. Three linear regressions were calculated using the strata Kruskal-Wallis H as the independent variable and along-shelf distance (km), cross-shelf distance (km), and depth (m) values as the dependent variables to test whether distribution changes were coherent in the along-shelf, cross-shelf, and depth dimensions.

For larvae, three bimonthly seasons representing the early (March – April), peak (May – June), and late (July – August) larval seasons were examined. We compared the Marine Resources Monitoring, Assessment and Prediction (MARMAP; 1977 - 1987) and EcoMon (1999 - 2015) programs (Figure 1). We also compared timing of larval occurrence between the time periods to infer changes in timing of spawning, using similar methods used to examine changes in distribution.

For juveniles and adults, the number of witch flounder caught per tow during the NEFSC bottom trawl surveys were calibrated to Albatross units for collections from 2009 onward. No length based correction used, and the number per per tow was divided by 3.257177 (Miller et al. 2010) to transform from Bigelow to Albatross units. For juvenile (< 30 cm) and adult (>= 30 cm) flounder, we calculated relative proportions of flounder for each NEFSC bottom survey: spring (March-April) and fall (September-October). We compared two 20 year time periods, 1970 - 1989 to 1996 – 2015.

Changes in juvenile and adult habitat

We examined changes in the capture of witch flounder during the NEFSC bottom trawl survey by habitat (e.g., water temperature and depth) in the Gulf of Maine region. Annual stratified mean bottom temperature (^{o} C) and depth (m) was calculated using stratified mean catch per tow of juvenile and adult witch flounder for survey stations. Linear regressions were calculated for juveniles and adults during each survey season to determine if there has been a significant change in stratified mean habitat. Finally, stratified mean habitats were compared to the annual means sampled during each survey to interperate changes in relation to the habitat sampled.

Results

Changes in distribution

Witch flounder larval distribution and timing of occurrence changed little over the past four decades (Fig. 2). Most change in relative larval proportions among stratum occurred during the late-larval season (Fig. 2C; July – August), with lower proportions in seven strata in the Mid-Atlantic Bight and Southern New Endland regions from 1999 to 2015. However, no significant change in along-shelf, cross-shelf, or depth dimensions occurred (Fig. 2D-F).

Juvenile witch flounder distribution shifted significantly over the past forty years (Fig. 3). Juveniles shifted northward and deeper in the spring, with higher proportions in the Gulf of Maine over the last 20 years (Fig. 3A, C, E). In the fall, juveniles shifed offshore, with higher proportions along the shelf edge in Southern New England, centeral Gulf of Maine, and Georges Bank (Fig. 3B, D).

Adult witch flounder distribution shifted significantly over the past four decades (Fig. 4). Adults shifted deeper in the spring, with higher proportions druing 1999 to 2015 in the centeral Gulf of Maine and lower proportions in the eastern Gulf (Fig. 4A, E). In the fall, adults shifed offshore, with higher proportions along the shelf edge in Southern New England, centeral Gulf of Maine, and Georges Bank (Fig. 4B, D).

Changes in juvenile and adult habitat

The changes in juvenile and adult witch flounder distributions resulted in significant changes stratified mean habitat. Stratified mean bottom water temperature increased significantly during the spring survey (Fig 5A) for both juveniles (p-val ≤ 0.02, df = 46, r^2 = 0.11, slope = 0.04) and adults (p-val ≤ 0.04, df = 46, r^2 = 0.09, slope = 0.03). There was no significant change in stratified mean bottom water temperature for either life-stage in the fall (Fig. 5B). During the spring survey, witch flounder were caught at or near the average bottom water temperature sampled during the survey (Fig. 5A). Witch flounder were caught about 7 ^{o}C below the average bottom water temperature sampled during the fall survey (Fig. 5B). Witch flounder also significantly increased stratified mean depth during the spring and fall surveys (Fig. 6) for both juveniles (spring: p-val ≤ 0.001, df = 46, r^2 = 0.33, slope = -0.87; fall: p-val ≤ 0.001, df = 51, r^2 = 0.34, slope = -0.77) and adults (spring: p-val ≤ 0.001, df = 46, r^2 = 0.25, slope = -0.57; fall: p-val ≤ 0.001, df = 51, r^2 = 0.22, slope = -0.34). Juvenile and adult witch flounder used to be collected near or above the mean depth sampled during the bottom trawl surveys before about 1985, but now are caught mostly below the mean depth sampled, particularly for juveniles (Fig. 6).

Summary

The changes in distribution and habitat for witch flounder juveniles and adults relate to the terms of reference 2 and 3 for SARC62.

2. Present available federal, state, and other survey data, indices of relative or absolute abundance, recruitment, etc. Characterize the uncertainty and any bias in these sources of data and compare survey coverage to locations of fishery catches. Select the surveys and indices for use in the assessment.

- Changes in depth and temperature may be affecting estimates of catchability
- Estimates of catchability may be varying by size and/or age

3. Investigate effects of environmental factors and climate change on recruitment, growth and natural mortality of witch flounder. If quantifiable relationships are identified, consider incorporating these into the stock assessment.

- Changes in temperature preferences may vary with size and/or age
- Change in temperature by juveniles warrents evaluating effect of temperature on recruitment

References

Miller T.J., C. Das, P.J. Politis, A.S. Miller, S.M. Lucey, C.M. Legault, R.W. Brown, P.J. Rago. 2010. Estimation of Albatross IV to Henry B. Bigelow calibration factors. Northeast Fish Sci Cent Ref Doc. 10-05; 233 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026, or online at: http://www.nefsc.noaa.gov/publications/crd/crd1005/

Walsh H.J., D.E. Richardson, K.E. Marancik, J.A. Hare. 2015. Long-Term Changes in the Distributions of Larval and Adult Fish in the Northeast U.S. Shelf Ecosystem. PLoS ONE 10(9): e0137382. doi: 10.1371/journal.pone.0137382.

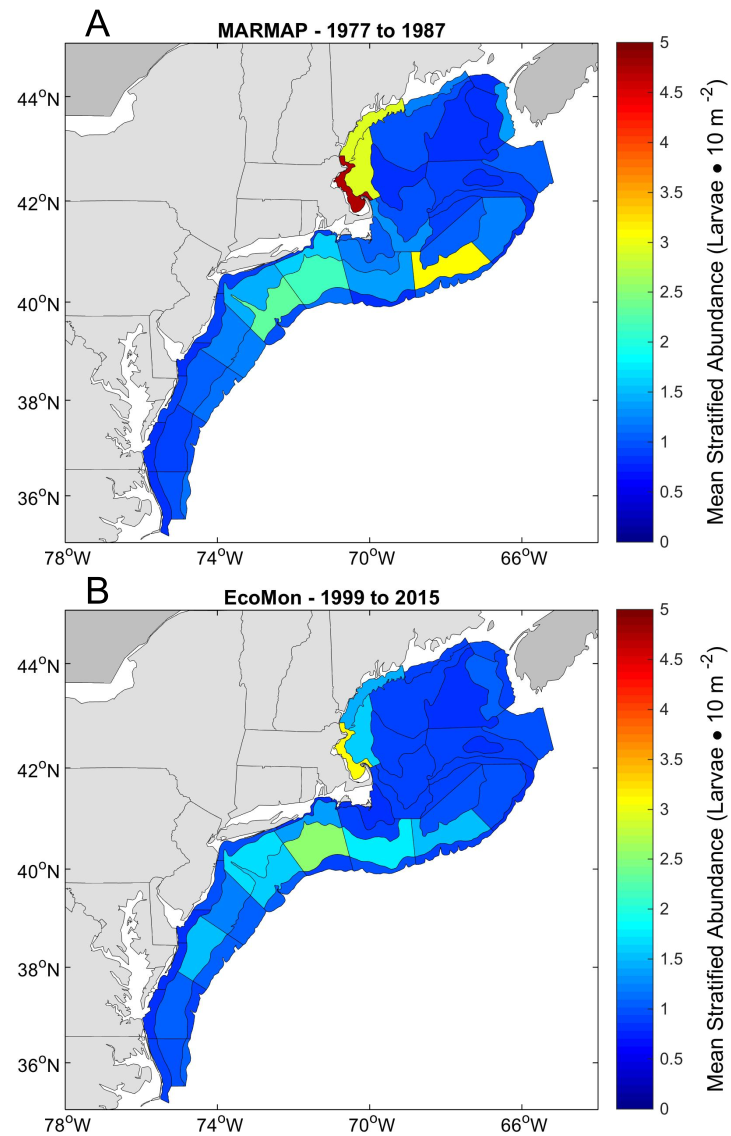

Figure 1. Larval witch flounder (*Glyptocephalus cynoglossus*) stratified mean abundance collected during Marine Resources Monitoring, Assessment and Prediction (MARMAP; A) and Ecosystem Monitoring (EcoMon; B) programs.

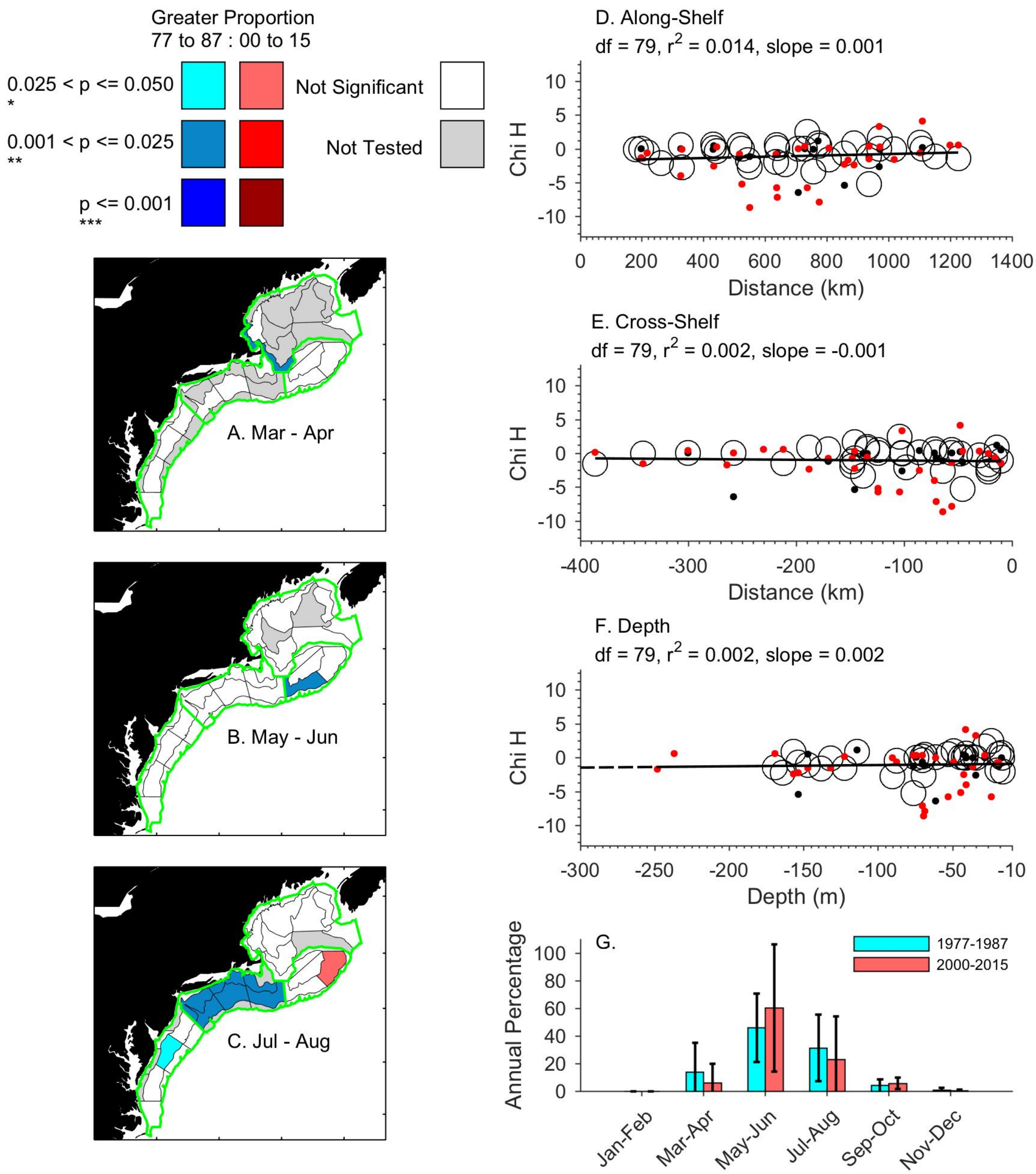

Figure 2. Spatial and seasonal distribution of larval witch flounder (*Glyptocephalus cynoglossus*) in the Northeast U.S. Shelf Ecosystem. Change in spatial distribution of larval in the March – April (A; •), May – June (B; O), and July – August (C; •) were examined in the along-shelf (D), cross-shelf (E), and depth (F) directions. Larval witch flounder did not shift significantly spatially or seasonally (G).

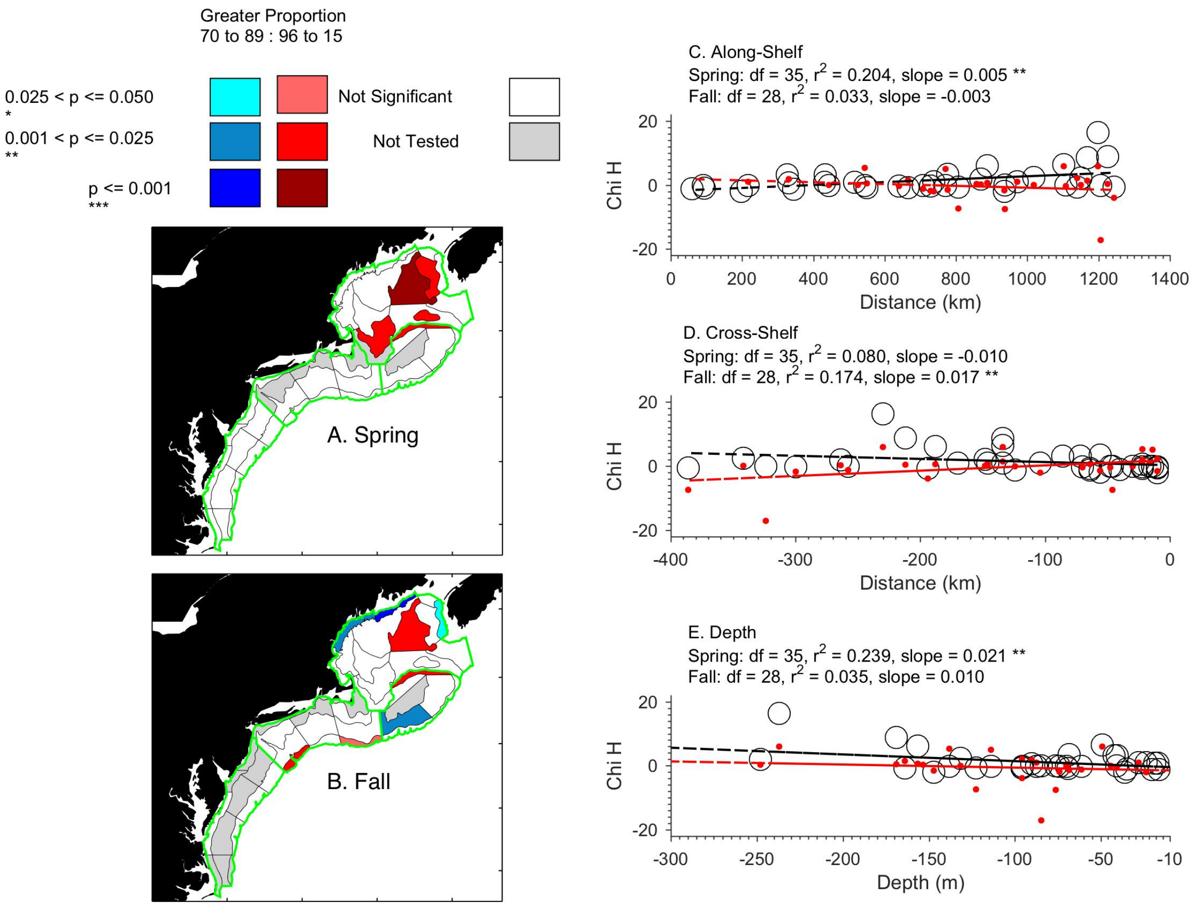

Figure 3. Spatial distribution of juvenile (< 30 cm) witch flounder (*Glyptocephalus cynoglossus*) in the Northeast U.S. Shelf Ecosystem. Change in distribution of juveniles in the spring (A; O) and fall (B; •) were examined in the along-shelf (C), cross-shelf (D), and depth (E) directions. Witch flounder juveniles shifted significantly northward (C) and deeper (E) in the spring, and offshore (D) in the fall.

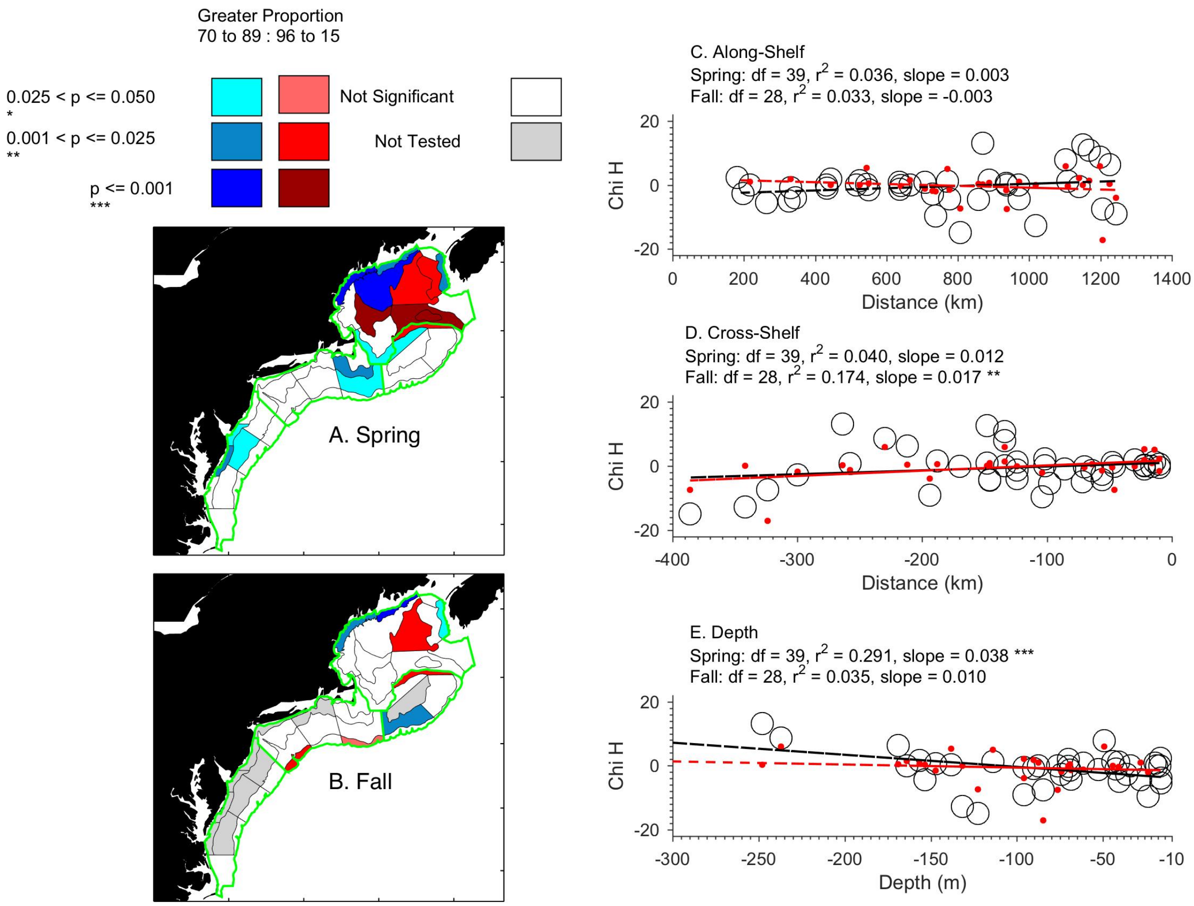

Figure 4. Spatial distribution of adult (>= 30 cm) witch flounder (*Glyptocephalus cynoglossus*) in the Northeast U.S. Shelf Ecosystem. Change in distribution of adults in the spring (A; O) and fall (B; •) were examined in the along-shelf (C), cross-shelf (D), and depth (E) directions. Witch flounder adults shifted significantly deeper (E) in the spring and offshore (D) in the fall.

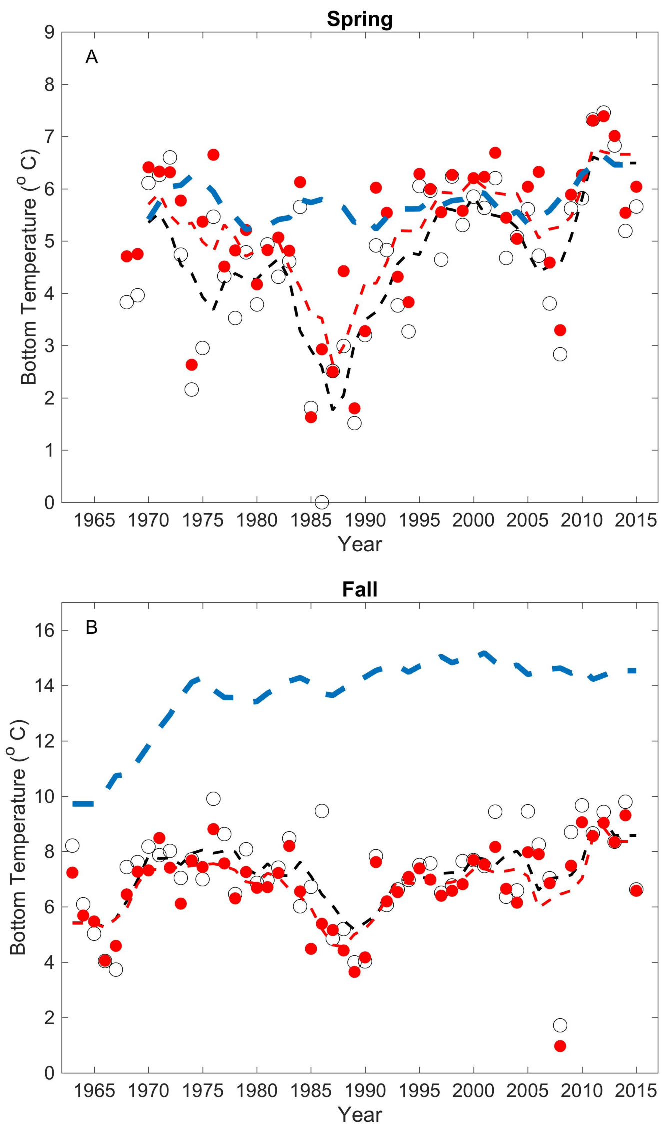

Figure 5. Stratified mean bottom water temperature (symbols) and 5-year moving average (line) of juvenile (< 30 cm; O) and adult witch flounder (>= 30 cm; •) collected in the Gulf of Maine during the NEFSC spring (A) and fall (B) bottom trawl surveys. Mean bottom water temperature of all stations sampled in the region is shown as a 5-year moving average (-).

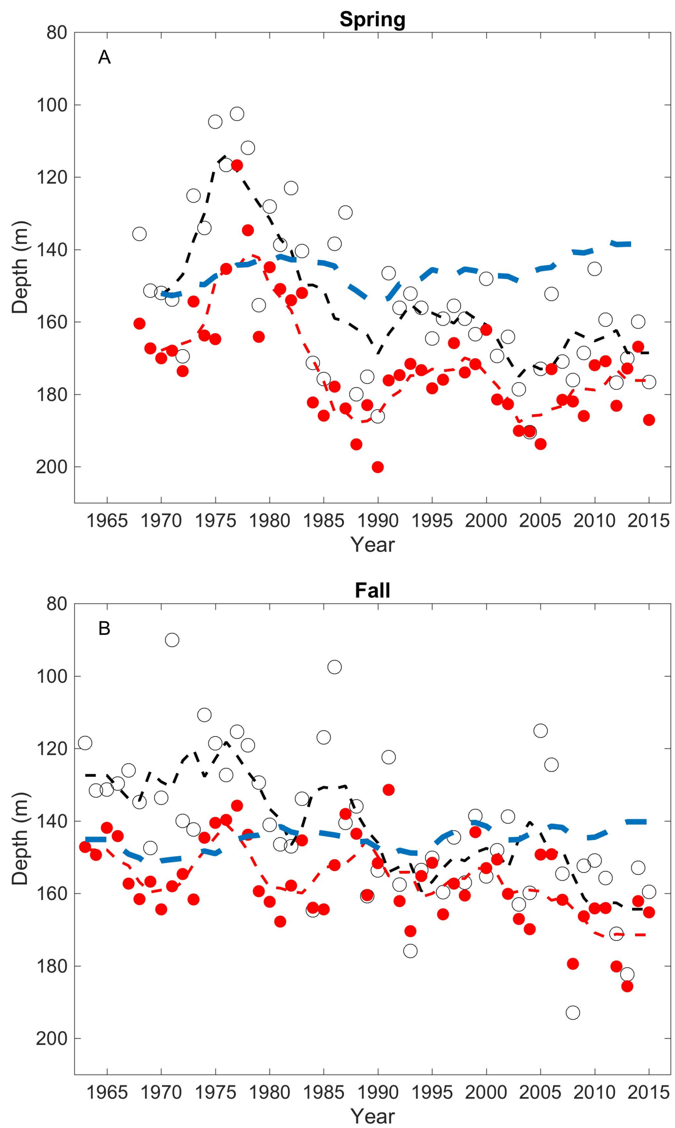

Figure 6. Stratified mean depth (symbols) and 5-year moving average (line) of juvenile (< 30 cm; O) and adult witch flounder (>= 30 cm; •) collected in the Gulf of Maine during the NEFSC spring (A) and fall (B) bottom trawl surveys. Mean bottom water temperature of all stations sampled in the region is shown as a 5-year moving average (-).